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Weinberg

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(54) **MOUNTING METHOD FOR SATELLITE CRASH SENSORS**

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G07C 5/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G07C 5/008*** (2013.01)

(58) **Field of Classification Search**
CPC G01P 1/02; H01L 21/673; H01L 21/6779; H01L 21/68778; H01L 2924/15; H01L 2924/171; H01L 2924/1711; H01L 2924/1715; H01L 2924/17151; H01L 2924/181; H01L 2924/1811; G07C 5/008
See application file for complete search history.

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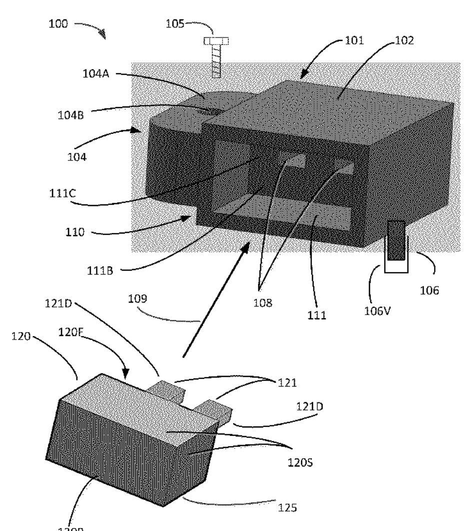
(57) **ABSTRACT**

A satellite sensor system includes a base unit and a packaged motion sensor configured to be removably couplable to the base unit. The base unit is configured to mount to a vehicle and to faithfully transmit vehicle motion to an attached sensor.

20 Claims, 8 Drawing Sheets



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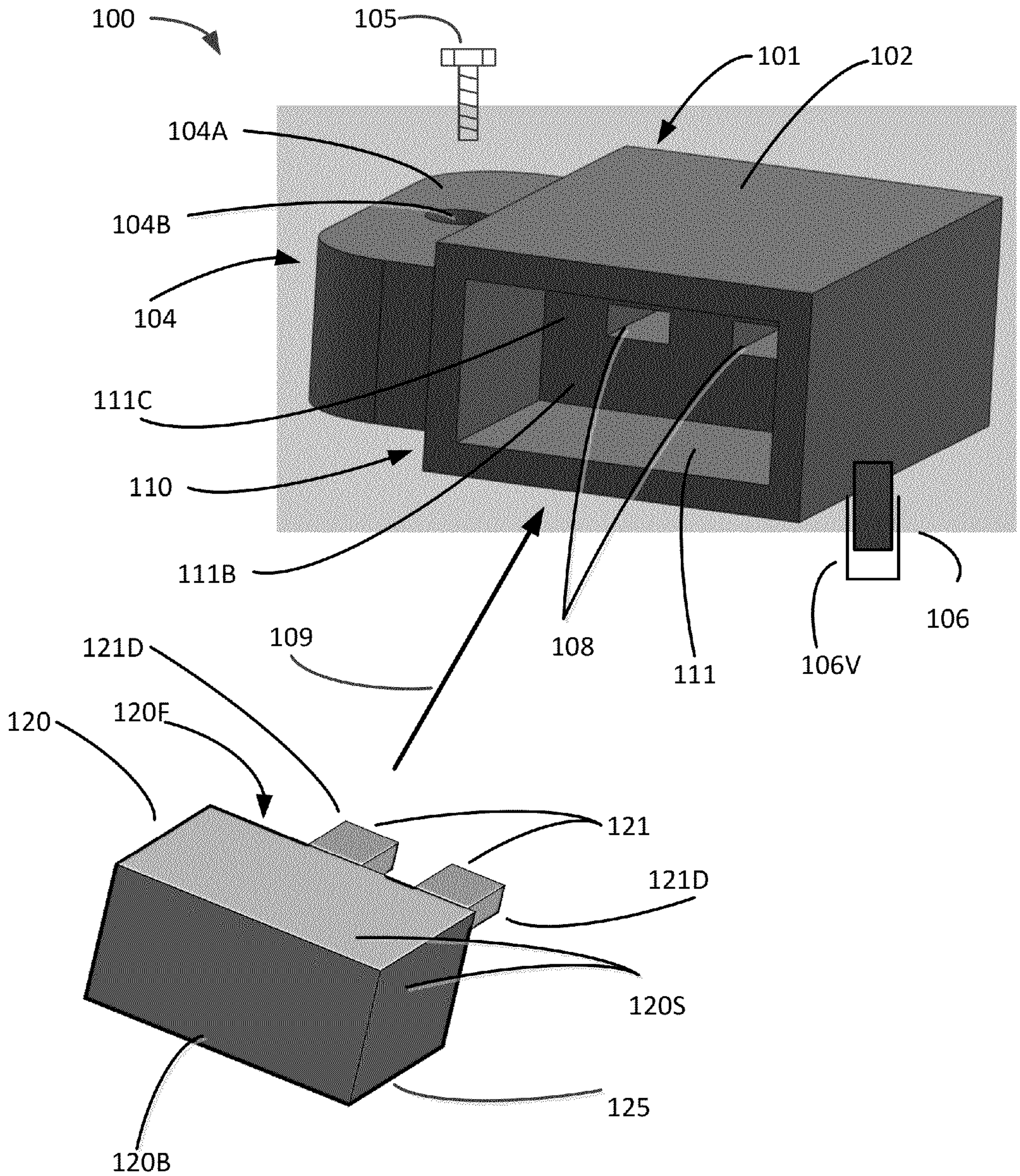
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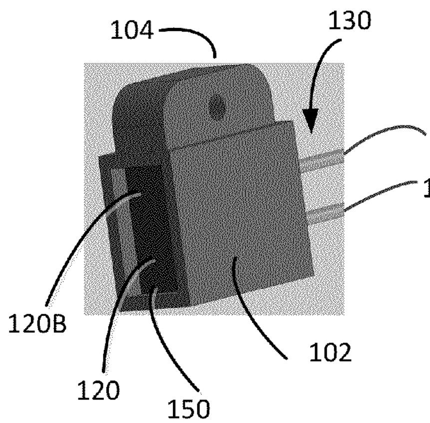
Fig. 1A



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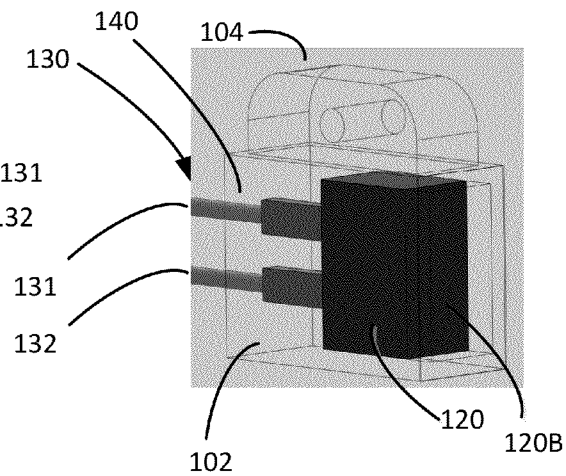


Fig. 1C

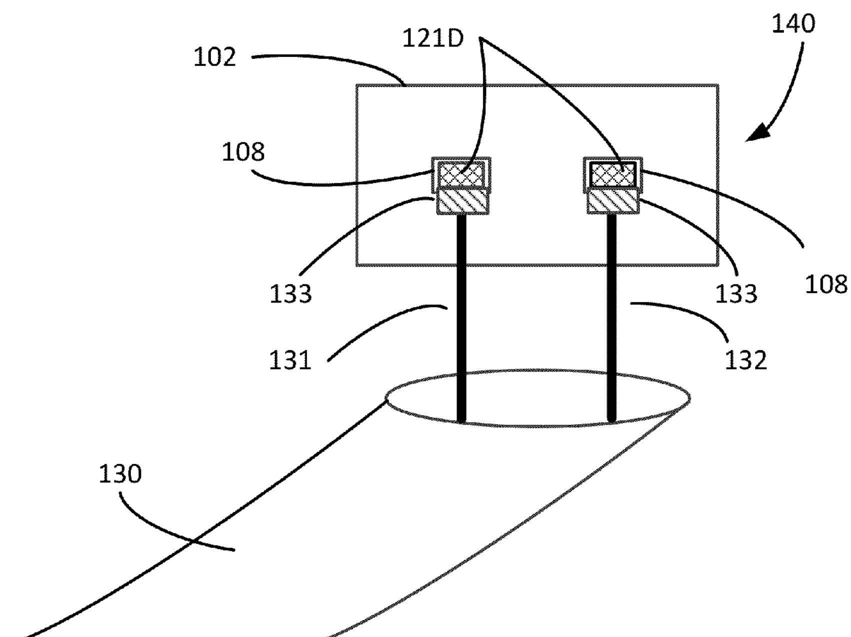


Fig. 1D

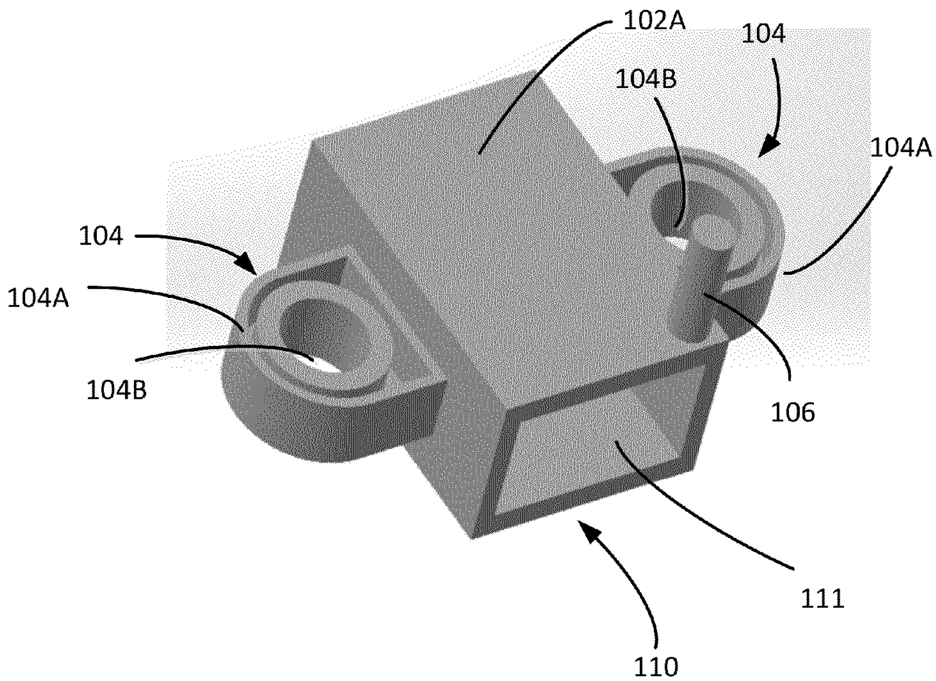


Fig. 1E

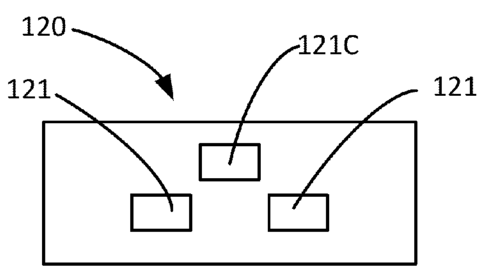


Fig. 4D

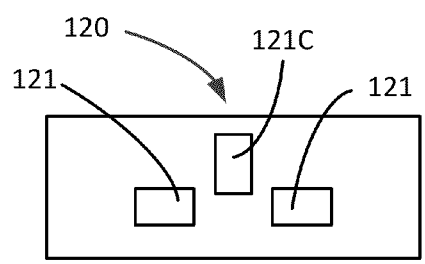


Fig. 4E

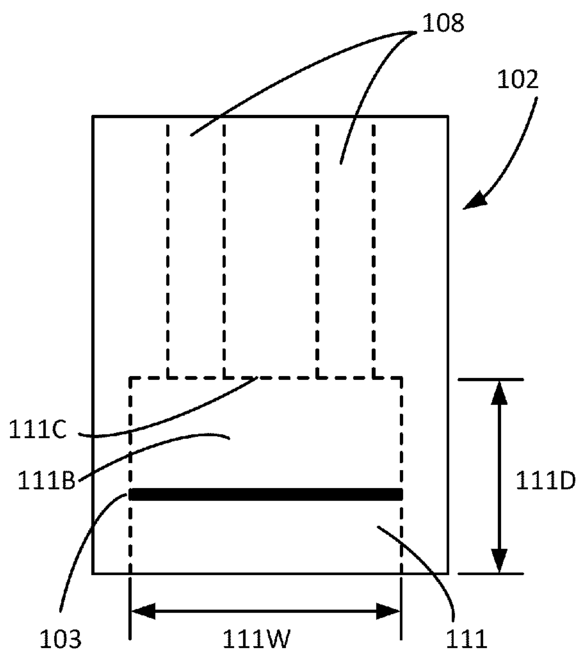


Fig. 2A

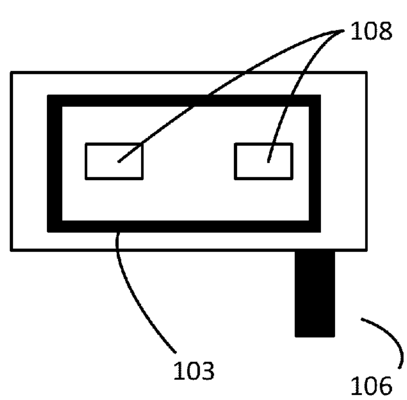


Fig. 2B

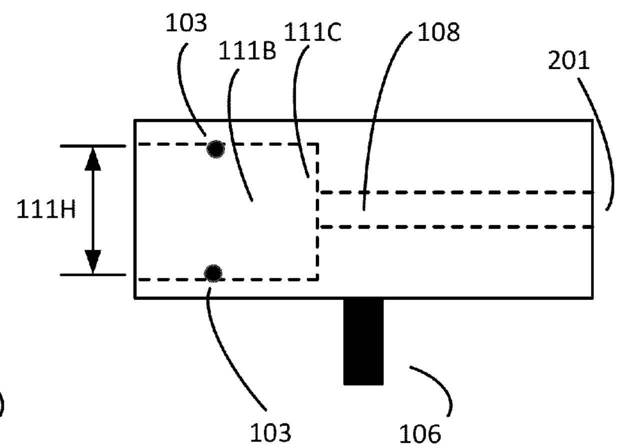


Fig. 2C

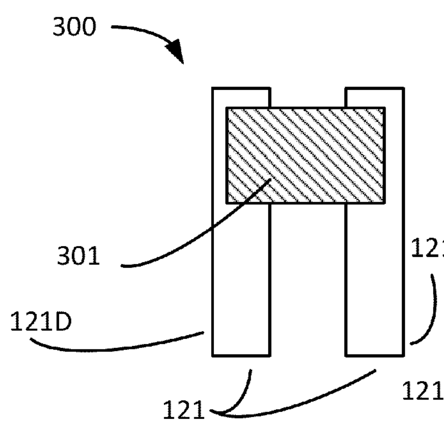


Fig. 3A

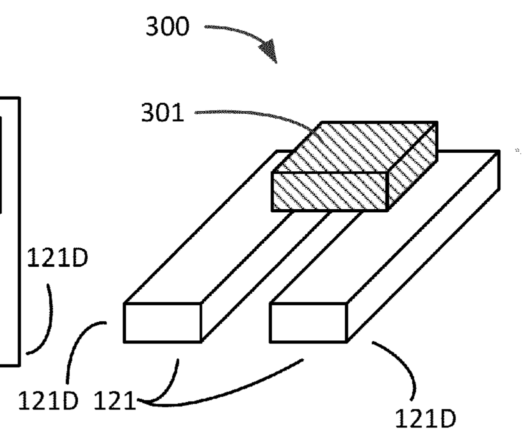
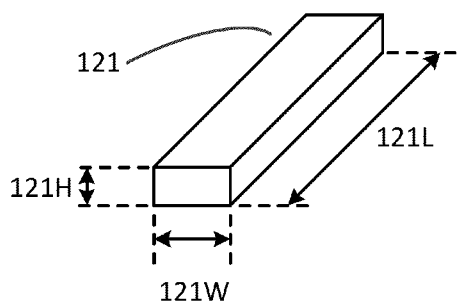


Fig. 3B



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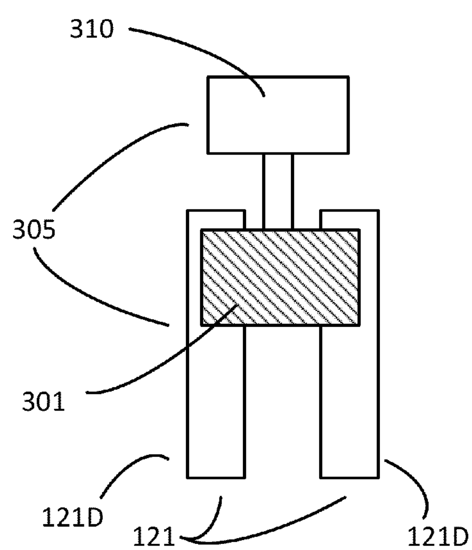

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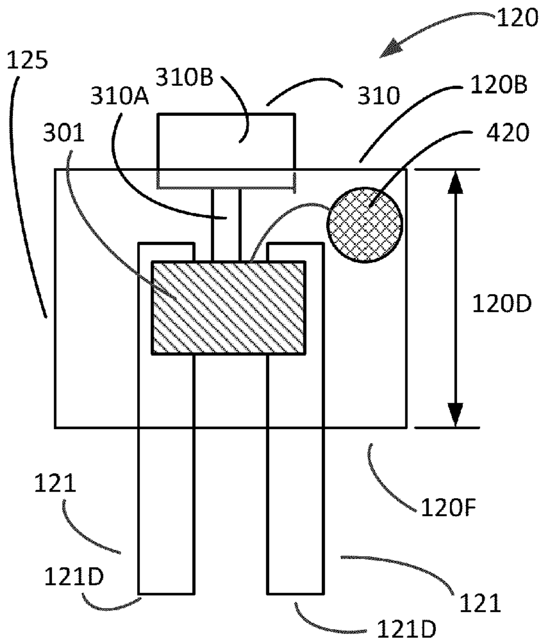
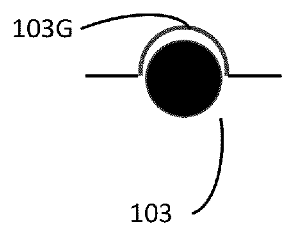


Fig. 4A



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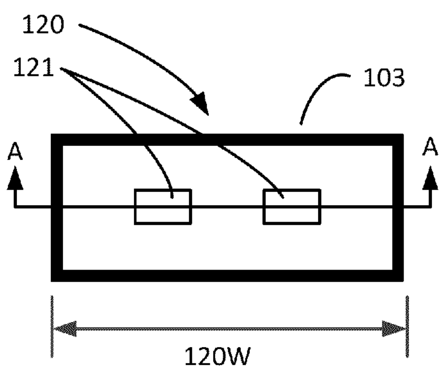
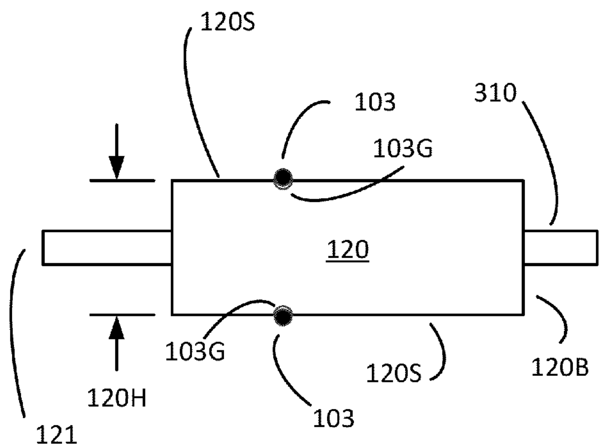


Fig. 4B



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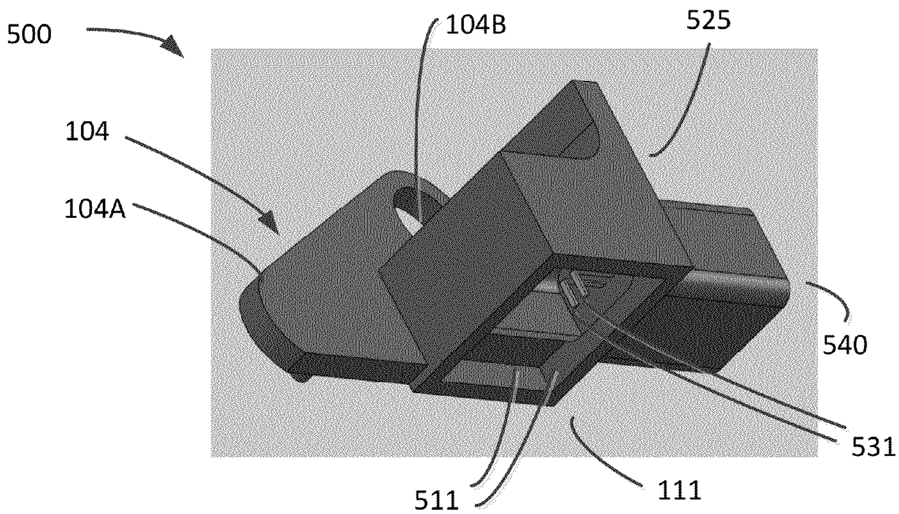


Fig. 5A

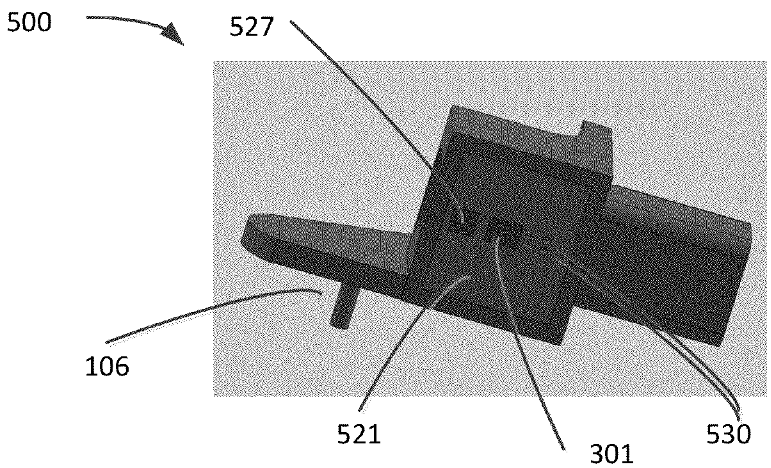


Fig. 5B

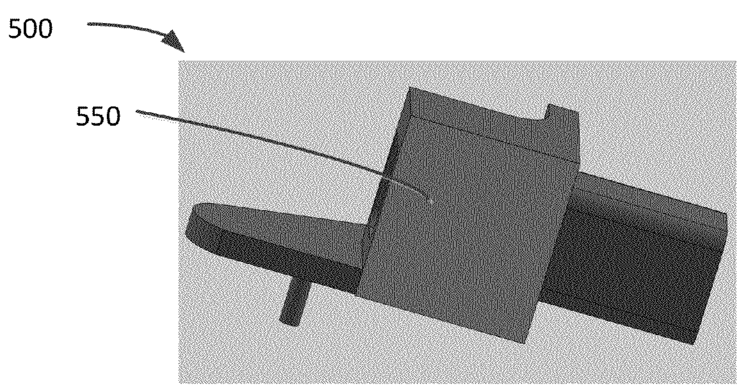
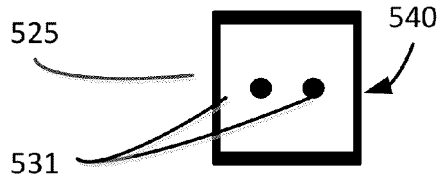


Fig. 5C



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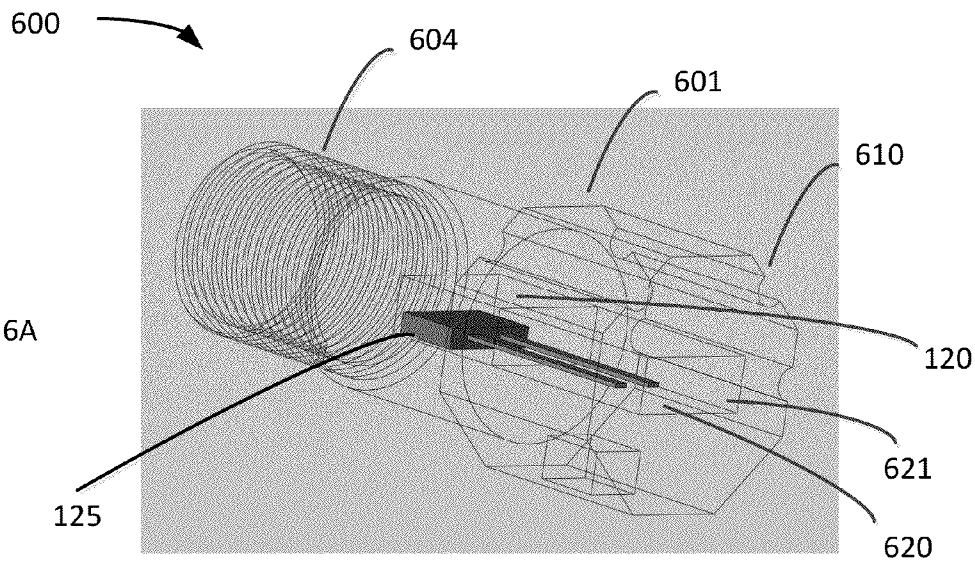

Fig. 6A

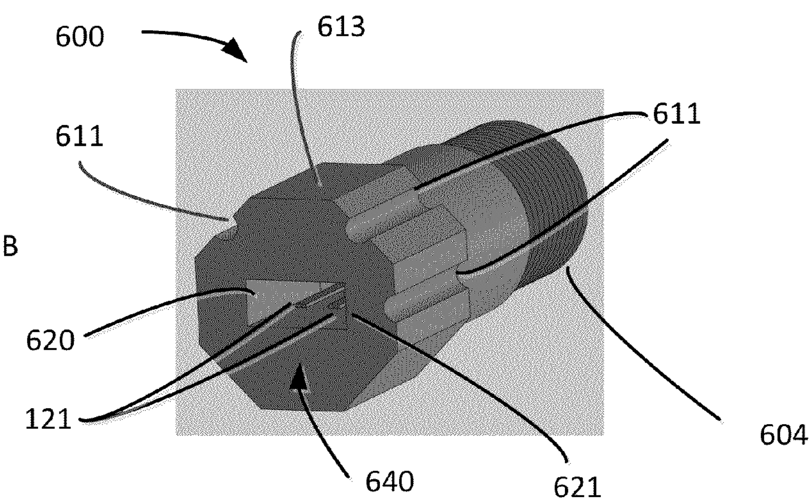

Fig. 6B

MOUNTING METHOD FOR SATELLITE CRASH SENSORS

RELATED APPLICATIONS

This patent application claims priority from provisional U.S. patent application No. 61/831,338, filed Jun. 5, 2013, entitled, "Mounting Method for Satellite Crash Sensors," and naming Harvey Weinberg as inventor, the disclosure of which is incorporated herein in its entirety.

TECHNICAL FIELD

The present invention relates to satellite sensors in a vehicle, and more particularly to mounting satellite sensors in vehicles.

BACKGROUND ART

It is known in the prior art to use satellite sensors in a vehicle to monitor various vehicle motions for the purposes of engaging safety systems. For example, an accelerometer might be mounted to a vehicle for determining whether the vehicle has been in a crash. The accelerometer's output signal or data is typically processed by an electronic control unit ("ECU") or other vehicle system to determine whether to deploy an airbag, or other vehicle safety system.

Such satellite sensors are typically mounted on circuit boards along with other components such as a wiring harness interface, and sealed in a housing to create a satellite sensor module. The module is then secured to the vehicle. During the manufacture of the vehicle, a worker attaches a flexible portion of the vehicle's wiring harness to the wiring interface in the housing. As such, a satellite sensor module is expensive to manufacture and test, and installing a satellite sensor module is expensive and labor intensive, and replacing or repairing a satellite sensor module is also expensive and labor intensive.

SUMMARY OF THE EMBODIMENTS

A first embodiment of a device for removably coupling a MEMS sensor to a vehicle includes a body, the body not including a MEMS sensor; a mounting device coupled to the body, and configured to affix the body to the vehicle; and a sensor interface coupled to the body, the sensor interface configured to accept a MEMS sensor module. In other embodiments, a device for coupling a MEMS sensor to a vehicle, includes a body forming a sensor interface; a cable integrally extending from the body; and a mounting device coupled to the body, and configured to affix the body to the vehicle, the sensor interface configured to accept a MEMS sensor module, the MEMS sensor module being electrically connected with the cable when accepted by the sensor interface.

In some embodiments, the sensor interface configured to removably accept a MEMS sensor module, and in some embodiments, the sensor interface is configured to provide an electrical interface with the MEMS sensor module, and the device further comprising a wiring harness interface. The harness interface may be configured to electrically couple directly to a MEMS sensor module when such a MEMS sensor module is coupled to the sensor interface, such that the MEMS sensor module is not in electrical contact with the body.

The sensor interface may further be configured such that the electrical interface is environmentally sealed when a sensor module is coupled to the sensor interface. To that end, a sensor module and/or a base unit may include a sealing member.

In some embodiments, the body further comprises a local power storage element, such as a battery for example, configured to provide power to a MEMS sensor module when such a MEMS sensor module is coupled to the sensor interface.

In some embodiments, mounting device includes an aperture passing completely through the body, and configured to receive a fastener and to allow the fastener to physically couple to the vehicle. The aperture may have a circular or non-circular cross-section, and may include internal threads. In other embodiments, the mounting device includes a threaded shank.

In another embodiment, a packaged MEMS sensor includes a support structure, the support structure comprising a plurality of legs, each of the legs having a mounting end and a distal end, and having a thickness of greater than 0.32 inches; a MEMS sensor physically coupled to the legs; and a casing encapsulating the MEMS sensor and partially encapsulating the support structure, such that the distal ends of the legs are exposed, and are configured to removably couple to a sensor interface in a vehicle mounting apparatus. The casing may be configured to mate with the sensor interface so as to form an environmental barrier surrounding the plurality legs.

According to various embodiments, each of the plurality of legs may be electrically conductive, and electrically isolated from each of the remaining legs, and the MEMS sensor is electrically coupled to the plurality of legs.

In some embodiments, each of the plurality of legs is electrically isolated from each of the remaining plurality of legs, and each of the plurality of legs is configured to carry an electrical signal to and/or from the MEMS sensor.

In some embodiments, the packaged MEMS sensor also includes a wireless communications circuit configured to communicate with a host vehicle, and each of the plurality of legs is non-conductive. Also, in some embodiments, the MEMS sensor includes a wireless communications circuit configured to communicate with the vehicle, and each of the plurality of legs is electrically conductive and is electrically coupled to each of the remaining plurality of legs.

In some embodiments, the sensor also includes a pull tab extending from the casing. The pull tab may be part of the support structure.

According to another embodiment, a method of fabricating a satellite sensor assembly includes providing a MEMS sensor die; production testing the MEMS sensor die; fabricating a sensor assembly by mounting the MEMS sensor die onto a substrate and overmolding the substrate and its sensor; production testing the sensor assembly; and installing the sensor assembly in the vehicle without further production testing.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing features of embodiments will be more readily understood by reference to the following detailed description, taken with reference to the accompanying drawings, in which:

FIG. **1**A schematically illustrates an embodiment of a satellite sensor mounting system;

FIGS. **1**B and **1**C schematically illustrate various embodiments of a sensor module coupled with a mounting body;

FIG. **1**D schematically illustrates an embodiment of a wiring harness interface;

FIG. **1**E schematically illustrates an embodiment of a sensor module;

FIGS. **2A-2C** schematically illustrate various embodiments of a mounting body in orthographic views;

FIGS. **3A-3D** schematically illustrate various embodiments and features of certain components of a sensor module;

FIGS. **4A-4C** schematically illustrate various embodiments of a sensor module in orthographic views;

FIGS. **4D-4E** schematically illustrate various embodiments of sensor module leg configurations;

FIG. **4F** schematically illustrates a gasket and groove;

FIGS. **5A-5D** schematically illustrate various embodiments of a satellite sensor mounting system;

FIGS. **6A-6B** schematically illustrate various embodiments of a satellite sensor mounting system.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Various embodiments provide simpler, more cost-effective satellite sensor systems that are also easier to install and maintain than previous satellite sensor systems. A first embodiment includes a packaged sensor device configured to be coupled and removed from a base unit. The base unit is configured to be affixed to the vehicle so as to faithfully transmit motion of the vehicle to a sensor coupled to the base unit. In some embodiments, the sensor system may be configured for wireless communication with an ECU or other vehicle system, while in other embodiments the base unit includes a wiring harness interface that provides for power and/or communications connections between the wiring harness and the sensor. As such, the sensor is easily installed, and easily removed and replaced.

An embodiment of a satellite sensor system **100** is schematically illustrated in FIG. **1A**, and includes a base **101** and a sensor module **120**. The base unit **101** is configured to attach to a vehicle and is configured to separably couple to the sensor module **120**, and the sensor module **120** is configured to removably attach to the base unit **101**. Various embodiments of base unit bodies or mounting bodies (e.g., **102**) and sensor modules (e.g., **120**) are schematically illustrated in additional figures, as described below.

The base unit **101** includes a body **102** having a sensor interface **110** configured to receive a sensor (e.g. sensor module **120**), and to be affixed to a vehicle. In various embodiments, the sensor interface **110** and sensor module **120** are configured such that the sensor module **120** is removable from the sensor interface **110**, and therefore removable from body **102**. In other words, the sensor module **120** may be inserted or installed into body **102** such that the sensor module is affixed to the vehicle and is functional for its intended purpose (e.g., sensing vehicle motion), and yet can be selectively removed, for example in the case of repair or replacement. In preferred embodiments, when a sensor module **120** is affixed to a host vehicle via a body **102**, the sensor module **120** will receive at least 90% of the energy of a vibration or other motion of the host vehicle through the base unit **101**. In other embodiments, the sensor module **120** will receive at least 95% or 99% or 100% of such energy.

To that end, in some embodiments, the base unit **101** includes, or is coupled to, a mounting device, or mounting interface **104** configured to mount the body **102** to the vehicle. For example, in the embodiment of FIG. **1A**, the mounting interface includes a mounting tab **104A** having a fastener aperture **104B**. The fastening aperture **104B** passes completely through the mounting tab **104A** and is configured to allow a fastener **105**, such as a threaded screw, pin, rivet, or cotter pin to name but a few examples, to pass through the mounting tab **104A** and attach to the vehicle. In some embodiments, the fastening aperture **104B** is threaded (e.g., has internal threads) to mate with a threaded fastener, while in other embodiments, the fastening aperture **104B** has a smooth bore.

In some embodiments, the fastening aperture **104B** has a cylindrical shape, and therefore has a circular cross-section. In other embodiments, however, the fastening aperture **104B** has an oval, elliptical, or other non-circular cross section, and fastener **105** has a matching cross-section, such that the shapes cooperate to resist rotation of the body **102** around the fastener **105**.

In some embodiments, the mounting tab **104A** is integral to the body **102**, but in other embodiments, the mounting tab **104A** may be a separate device attached to the body **102**.

In some embodiments, the body **102** and/or the mounting tab **104A** includes an anti-rotation pin **106** or other device that prevents the body **102** from rotating around the fastener **105** when the body **102** is mounted to a vehicle via a fastener. To that end, the anti-rotation pin **106** is configured to fit into a corresponding aperture or trench **106V** in the vehicle. In the embodiment of FIG. **1A**, the anti-rotation pin **106** extends from the body **120** in a direction parallel to the axis of aperture **104B**, such that the anti-rotation pin **106** is parallel to the fastener **105**.

Another embodiment of a body **102A** is schematically illustrated in FIG. **1A**, and includes two mounting tabs **104** as described above, as well as an anti-rotation pin **106**, and many other features of body **102** of FIGS. **1A-1D**.

In other embodiments, the body **102** is molded or otherwise integral to another element of its host vehicle, such as a bracket that serves another purpose within the vehicle. In such embodiments, the body is affixed to the vehicle as part of the bracket, and would not require an additional mounting device **104**. A sensor module **120** may then be installed into a sensor interface **110** of the body, as with other embodiments.

The body **102** also includes a sensor interface **110** configured to accept a sensor module (e.g., sensor module **120**, for example). In the embodiment of FIG. **1A**, the sensor interface **110** is defined in part by a cavity **111** in the body **102**. The inner dimensions of the cavity **111** (e.g., height **111H**, width **111W**, depth **111D**; see FIGS. **2A-2C**; see, e.g., FIGS. **4A-4C**) are greater than the corresponding outside dimensions (e.g., height **120H**, width **120W**, depth **120D**) of a corresponding sensor module (e.g., **120**), such that the sensor module, or at least a portion of a sensor module, fits into the cavity **111**. As indicated by the arrow **109** of FIG. **1A**, one face **102F** and at least a portion of the sides **102S** of the sensor module **120** may be inserted into cavity **111**.

FIG. **1B** and FIG. **1C** schematically illustrate a system **100** in which a sensor module **120** is inserted into a body **102**. In these embodiments, the sensor module **120** fits completely into the cavity **111**, such that no part of the sensor module **120** extends from the cavity **111**. Nevertheless, the sensor module **120** is not completely encapsulated by the body **102**, because at least one face (e.g., **120B**) of the sensor module is exposed from within the cavity **111**. Indeed, in some embodiments, a portion of the cavity **111** not occupied by the sensor module **120** may be filled with a sealing material **150** so as to secure, and in some embodiments even to seal, the sensor module **120** within the body **102**. In other embodiments, a portion of the sensor module **120** may extend from the body **102**, such as from cavity **111**.

In some embodiments, the cavity **111** and sensor module **120** fit together so as to form an environmental barrier or seal against the incursion into the cavity **111** of contaminants, such as moisture or dust, etc., that might interfere with the interface (e.g., physical or electrical interface) between the sensor module **120** and the body **102**. In particular, such an environmental barrier or seal prevents or hinders the incursion of such contaminants to the inside end **111**B of the cavity **111**. For example, in some embodiments, the environmental barrier is configured to meet or exceed the IP67 standard.

To that end, the dimensions (**111**H, **111**W and **111**D) of the cavity **111** and the sensor module **120** are configured such that the sensor module **120** fits snugly into the cavity **111**. In other embodiments, however, one or both of the body **102** and sensor module **120** may include a gasket or seal member **103** to interface between the body **102** and sensor module **120**, as in FIG. **2**C for example. The gasket or seal member **103** forms an environmental barrier that prevents or impedes the incursion of contaminants to the inside end **111**B of the cavity **111**. For example, in some embodiments, the environmental barrier is configured to meet or exceed the IP67 standard. In such embodiments, the inside end **111**B of the cavity **111** may be defined as that portion of the cavity **111** between the gasket or seal member **103** and the back end **111**C of the cavity **111**.

As schematically illustrated in the embodiments of FIG. **1**B and FIG. **1**C, sensor module **120** is within the body **102**, but is still exposed. More specifically, a face **120**B of the sensor module **120** remains exposed to the external environment, and is even visible from outside the body **120**.

When a sensor module **120** is coupled to a base **102** via mounting interface **110**, each of the legs **121** of the sensor module **120** extends into a corresponding one of the apertures **108**. Indeed, in some embodiments, the legs **121** may extend completely through the apertures **108** and exit the body **102**. For example, in FIG. **1**C, the legs **121** of sensor module **120** extend through the body **102** (which is schematically illustrated as translucent in FIG. **1**C for purposes of illustration) to provide a wiring harness interface **140** to connect with corresponding conductors **131**, **132** of wiring harness (or cable) **130**. Indeed, in some embodiment's, apertures **108** may be lined with a conductive material, or may include a conductive liner, or may otherwise be conductive, so provide an electrical interface to legs **121**. In other embodiments, however, the body **102**, or at least the apertures **108**, are not conductive, so that the sensor module **120** is not in electrical contact with the body **102**. In some embodiments, as schematically illustrated in FIG. **1**D, the vehicle's wiring harness **130** includes connectors **133** configured to insert within the apertures **108** and make a physical and electrical connection to the legs **121**, such that there is a direct electrical connection between the sensor module **120** and the wiring harness **130**. In some embodiments, the wiring harness (or cable) **130** may be integrally coupled to the body **102** (e.g., integrally extend from the body **102**). In such embodiments, the cable **130** could not be removed or detached from the body **102** without damaging or destroying the cable **130**, the body **102**, or both. As such, the body **102** may secure, or help to secure, the wiring harness or cable **130** to the vehicle.

FIGS. **3**A and **3**B schematically illustrate certain internal components of a sensor module **120**.

Generally, the sensor **301** is a sensor (e.g., a micromachined or MEMS sensor) configured to sense one or more motions of a moving vehicle, and may include, without limitation, inertial sensors such as accelerometers and gyroscopes, bulk acoustic wave gyroscopes, etc. A "wireless sensor" is a sensor that includes (or is part of a system or module that includes) communications interface circuitry configured to communicate wirelessly with, for example, with an electronics control unit ("ECU") of a vehicle. Typically, a sensor **301** is configured to monitor vehicle motions that may indicate a need to deploy a safety system (e.g., a crash sensor configured to detect a sudden deceleration in order to deploy an air bag). In some embodiments, the sensor **301** may be configured to produce a digital output (e.g., it may include an analog-to-digital converter).

In the embodiment of FIGS. **3**A and **3**B, the sensor module includes two legs **121** and a sensor **301**. The sensor **301**, and portions (**121**E) of the legs **121** are enclosed or encapsulated into package or casing **125**, while distal ends **121**D of the legs **121** are exposed from the package. The sensor may be an accelerometer or gyroscope, to name but a few examples. The package or casing **125** may be injection molded polymer, as known in the art, or may include multiple parts that snap or fit together around the internal portions of the sensor module **120**.

In some embodiments, the legs **121** serve multiple functions. For example, the legs **121** serve a structural function. To that end, the legs must be sufficiently rigid and strong to provide a suitable connection to a base **102**. Such a physical or mechanical connection must be sufficient to faithfully transmit vibrations or other motions of the vehicle to the sensor **301**. For example, in some embodiments, the legs have a width **121**W of 0.33 inches and a height **121**H of about, less than or equal to 0.32 inches, as schematically illustrated in FIG. **3**C. In some embodiments, at least one of the height **121**H or the width **121**W of at least one leg **121** is greater than 0.32 inches.

Further, in some embodiments, the legs serve an electrical function. In particular, in some embodiments the legs **121** are conductive and electrically isolated from one another. The sensor **301** is electrically coupled to the legs **121**, such that the legs **121** serve to provide power to the sensor **301** (e.g., electrical power from the vehicle's electrical system via a wiring harness coupled to a body **102**) and/or carry signals to and/or from the sensor **301**, for example signals to and/or from the vehicle's electronics control unit.

In other embodiments, the legs **121** are conductive, but are do not provide a power or signal interface with the sensor **301**. In such embodiments, one or more legs, and/or a pull tab **130** as discussed below, may be electrically coupled to provide EMI protection for the sensor **301**.

In preferred embodiments, the legs **121** interface to the body **102** without solder or other conductive or non-conductive intermediary. In other embodiments, the legs extend through the body **102** and couple directly to the vehicle's wiring harness.

In some embodiments, however, one or more of the legs **121** may be non-conductive, and may thus serve only a structural function, such as in a sensor module **120** having a local power source (e.g., battery) and a wireless communications interface.

In addition, some embodiments include a pull tab **310** to facilitate removal of a sensor module **120** from a body **102**, for example when the sensor module needs to be replaced. To that end, a pull tab **310** has an internal portion **310**A configured to be encapsulated with other elements of the sensor module **120**, and an external portion **310**B configured to extend outside of the sensor module's housing **125** so as to be available to a user. In some embodiments, the pull tab **310** is a part of the support structure (or support framework) **305**, and in some embodiments, the internal portion **310**A is coupled to the sensor **301**, for example to provide physical support for the sensor.

FIGS. **4**A-**4**E schematically illustrate embodiments of sensor module **120**. FIG. **4**A is a cross-section (A-A) of a sensor module **120** and schematically illustrates the sensor module **120** having two legs **121** and a sensor **301** enclosed in a casing **125**. FIG. **4**A does not show a seal member **103**, to avoid cluttering the figure, but a seal member **103** is schematically illustrated in FIGS. **4**B and **4**C. The seal member **103** forms a continuous barrier or ring around the inside of cavity **111**. The sensor **301**, and a portion of each leg **121**, and a portion (**310**A) of the (optional) pull tab **310** are within the casing **125**, while a distal portion **121**D of each leg **121**, and a portion (**310**B) are outside of the casing **125**.

In the various embodiments, the casing **125** has a **6**-sided shape, with a depth (**120**D), width (**120**W) and height (**120**H) as schematically illustrated in FIGS. **4**A-**4**C.

In embodiments that include a seal member **103**, the casing **125** may include a groove **103**G to partially accept the seal member **103**, and to secure the seal member **103** in place. A seal member **103** is schematically illustrated in FIGS. **4**B and **4**C. FIG. **4**F includes a larger schematically illustration of a seal member **103** disposed in a groove **103**G as in FIG. **4**C for example, although when a sensor is installed in the cavity **111** the seal member **103** would be pressed further into the groove **103**.

Some embodiments include a local power source **420**, such as a battery for example. The power source **420** is electrically coupled to the sensor **301** and configured to supply operating power to the sensor **301**. As such, some embodiments do not draw, or do not need to draw, power from a host vehicle's power systems. If the sensor **301** includes a wireless interface, the sensor module **120** may not need to have any hardwired connection to the vehicle's electrical system, and as such may not have an electrical connection to the vehicle's wiring harness.

Some embodiments of sensor modules **120** may have more than two legs **121**. For example, some embodiments have may have three or more legs **121**. Some embodiments having three legs **121** are schematically illustrated in FIGS. **4**D and **4**E, for example. In FIG. **4**D, a third leg **121**C may be similar or identical to legs **121**, but is located such that it is not in-line with legs **121**. In FIG. **4**E, leg **121**C is oriented such that its width **121**W is not parallel to the width **121**W of the other legs **121**.

Such addition legs may serve to provide additional mechanical strength to the sensor module **120**, and also to the system **100** when a sensor module is coupled to (e.g., plugged into) a base unit **102**. In addition, such additional legs may provide an additional electrical connection to a wiring harness.

For a sensor module **120** with multiple legs **121**, a body **102** has a corresponding number of apertures **108** to accept the legs **121** when the sensor module **120** is coupled to the body **102**. Further, the placement and orientation of the legs **121**, **121**C and the corresponding aperture **108** may provide a pattern that prevents a sensor module **120** from being mated to a body **102** in any orientation other than a single, correct orientation. Indeed, in some embodiments, some legs **121** may be conductive, while other legs (e.g., **121**C) may be non-conductive, or may even be a part of casing **125**, and serve only a mechanical/structural function (e.g., for mating to a body **120**) as described above.

An alternate embodiment of a sensor system **500** is schematically illustrated in FIGS. **5**A-**5**C. System **500** includes many of the same features as system **100**, as denoted by common reference numbers, although the shapes, locations, and orientations of such features may vary.

In system **500**, the sensor module **520** includes a sensor **301** coupled to a substrate **521**, and the substrate **521** is at least partially, and in some embodiments completely, within the cavity **111**, as schematically illustrated in FIG. **5**B. For example, the sensor module **520** may be snap-fit or press-fit into cavity **111**, such that it is held in place by frictional forces between the sensor module **520** and the walls **511** of the cavity **111**. The substrate **521** may also include other features **527**, such as a battery or RF (wireless) transceiver, for example.

The substrate **521** includes several apertures **530**, configured to mate with pins **531** extending from casing **125** into the cavity **111**. The pins **531** form an electrical connection with apertures **530**, and thereby to the circuitry (e.g., sensor **301**) on the substrate **521**. The pins **531** also extend through the body (e.g., **525**) to form a wiring harness interface **540**, as also schematically illustrated in FIG. **5**D.

In some embodiments, the cavity **111** is covered by a plate **550**, which encloses the substrate **521** and its components within cavity **111**. In some embodiments, the plate **550** is hermetically sealed to the casing **525** to provide an environmental seal to the cavity **111**.

FIGS. **6**A and **6**B schematically illustrate another embodiment **600** of a base unit **601** that includes a mounting device **604** having a threaded shank **605**. The base unit **601** may be metal, molded or machined or 3D-printed plastic, or other polymer. The base unit may include a head portion **610** in addition to the shank **605**, and the head portion **610** and shank **605** may form a single, integral unit. In some embodiments, the head portion **610** may have six-faces **613** configured to be driven with a socket wrench, for example, and/or may have features, such as grooves **611**, configured to interface with a mounting tool for purposes of turning or screwing the system **600** into a corresponding threaded aperture in a vehicle.

The base unit includes a recess **620** configured to receive a sensor module **120**. In particular, the casing **125** of the sensor module **120** is disposed within the recess **620** such that the legs **120** extend towards the opening **621** of the recess in the head portion **610**. The casing **125** of the sensor module **120** may fit snugly into the recess **620**, so as to be secured within the recess **620** by pressure or friction. As such, the sensor module **120** is secured within the recess **620**, such that the base unit **601** and the shank **605** faithfully transmit motion of the vehicle to the sensor module **120**. Further, the sensor module **120** may be removable from the recess **620** by pulling on the legs **121**, making repair or replacement of the sensor module **120** simple and inexpensive. In other embodiments, the sensor module may be secured within the recess **620** by an epoxy or other adhesive.

The legs **121** are exposed through the opening **621**, such that the legs **121**, the recess **620** and opening **621** form an interface for the vehicle's wiring harness. For example, a vehicle's wiring harness (e.g., **130**) may include one or more connectors (e.g., **133**) configured to slide within the recess **620** and make a physical and electrical connection to the legs **121**. As such, the recess **620** and legs **121** form a wiring harness interface **640**.

Various embodiments disclosed herein potentially provide benefits over previously-known sensor systems. Among the advantages are cost savings arising from the relative simplicity of the systems.

For example, a prior art automobile sensor system includes several levels of assembly, and several of the various components and sub-assemblies require testing at various points in the assembly and installation processes. A typical process for producing a prior-art sensor module includes the following steps: (a) fabricate the sensor (e.g., via a micromachining process); (b) test the sensors (e.g., at wafer level or die level); (c) fabricate a sensor assembly by mounting die and other components onto a substrate (which may be a printed circuit board) and overmolding the substrate and its sensor and other components; (d) test the sensor assembly; (e) fabricate a printed circuit board assembly mount the sensor assembly and other components onto a printed circuit board; (f) test the printed circuit board assembly; (g) mount the printed circuit board assembly into a mounting package, the mounting package configured to be mounted to a vehicle; and (h) mounting the mounting package in a vehicle and coupling the package to flexible portion of the vehicle's wiring harness. As described, the prior art required many steps, many components, and many tests. Each and all of these add complexity and cost to the final product.

In contrast, various embodiments disclosed herein can be fabricated and assembled with fewer fabrication steps and materials, and fewer testing steps. For example, a sensor according to various embodiments may require a process such as the following: (a) fabricate the sensor (e.g., via a micromachining process); (b) test the sensors (e.g., at wafer level or die level); (c) fabricate a sensor assembly by mounting die and other components onto a substrate (which may be, e.g., a printed circuit board or other substrate such as substrate **521**, or legs **121**) and overmolding, encapsulating or otherwise packaging the substrate and its sensor and other components; (d) test the sensor assembly. Once fabricated according to the foregoing steps, the sensor assembly (e.g., sensor module **120**) is ready to be installed in a vehicle by, for example, coupling the sensor module to a base unit (e.g., **101**) that is affixed to the vehicle. Among other things, the sensor assembly is ready to be installed in a vehicle without further production testing (i.e., testing performed to validate the proper outcome of the fabrication process). Of course, a complete sensor assembly may be tested at a later time, for example by a vehicle manufacturer, to confirm that the sensor assembly is still functional, but that is a post-production test or a validation text, and not a production test. In other words, the process of fabricating various embodiments as described above is considerably simpler and less expensive than processes for fabricating prior art sensor units.

As described, the process of fabricating various embodiments as described above may eliminate several components of the product (e.g., the printed circuit board assembly) and several process and testing steps [e.g., steps e-g, above]. As such, various embodiments stand to be less expensive in terms of component cost, assembly cost and text cost, and easier to fabricate. Indeed, the various embodiments even stand to be easier to install in a vehicle. Further, in various embodiments the sensor module can even be easily replaced or repaired because the sensor modules (e.g., module **120**) is removable from its base, such that the base may remain affixed to a vehicle even when the sensor module is removed or replaced.

Various embodiments of the present invention may be characterized by the potential claims listed in the paragraphs following this paragraph (and before the actual claims provided at the end of this application). These potential claims form a part of the written description of this application. Accordingly, subject matter of the following potential claims may be presented as actual claims in later proceedings involving this application or any application claiming priority based on this application. Inclusion of such potential claims should not be construed to mean that the actual claims do not cover the subject matter of the potential claims. Thus, a decision to not present these potential claims in later proceedings should not be construed as a donation of the subject matter to the public.

Without limitation, potential subject matter that may be claimed (prefaced with the letter "P" so as to avoid confusion with the actual claims presented below) includes:

P1. A device for removably coupling a MEMS sensor to a vehicle, comprising:

a body, the body not including a MEMS sensor;

a mounting device coupled to the body, and configured to affix the body to the vehicle; and

a sensor interface coupled to the body, the sensor interface configured to accept a packaged MEMS sensor.

P2. The device of potential claim P1, wherein the sensor interface configured to removably accept a packaged MEMS sensor

P3. The device of potential claim P1, wherein the sensor interface is configured to provide an electrical interface with the sensor, and the device further comprising a wiring harness interface.

P4. The device of potential claim P3, wherein the sensor interface is configured such that the electrical interface is environmentally sealed when such a MEMS sensor is coupled to the sensor interface.

P5. The device of potential claim P3, wherein the harness interface is configured to electrically couple directly to a packaged MEMS sensor when such a MEMS sensor is coupled to the sensor interface, such that the MEMS sensor is not in electrical contact with the body.

P6. The device of potential claim P1, wherein the body further comprises a local power storage element, configured to provide power to a MEMS sensor when such a MEMS sensor is coupled to the sensor interface.

P7. The device of potential claim P6, wherein the local power storage element is a battery.

P8. The device of potential claim P1, wherein the mounting device comprises an aperture passing completely through the body, and configured to receive a fastener and to allow the fastener to physically couple to the vehicle.

The embodiments of the invention described above are intended to be merely exemplary; numerous variations and modifications will be apparent to those skilled in the art. All such variations and modifications are intended to be within the scope of the present invention as defined in any appended claims.

What is claimed is:

1. A device for removably coupling a MEMS sensor to a vehicle, comprising:

a body forming a sensor interface;

a cable integrally extending from the body; and

a mounting device coupled to the body, and configured to affix the body to the vehicle,

the sensor interface configured to accept a MEMS sensor module, the MEMS sensor module being electrically connected with the cable when accepted by the sensor interface.

2. The device of claim **1**, wherein the sensor interface is configured to removably accept the MEMS sensor module.

3. The device of claim **1**, wherein the sensor interface has an electrical interface configured to electrically connect the MEMS sensor module with the cable.

4. The device of claim **2**, wherein the sensor interface is configured such that the electrical interface is environmentally sealed when the MEMS sensor module is coupled to the sensor interface.

5. The device of claim **1** further comprising the MEMS sensor module coupled with the sensor interface, the MEMS sensor module having sensor interconnects to electrically connect with the cable.

6. The device of claim **1**, wherein the body further comprises a local power storage element that is configured to provide power to a MEMS sensor module when the MEMS sensor module is coupled to the sensor interface.

7. The device of claim **1**, wherein the mounting device comprises an aperture passing completely through the mounting device, and configured to receive a fastener and to allow the fastener to physically couple to the vehicle.

8. The device of claim **7**, wherein the aperture has a non-circular cross-section.

9. The device of claim **8**, wherein the aperture comprises internal threads.

10. The device of claim **1**, wherein the mounting device comprises a threaded shank.

11. The device of claim **1** further comprising a seal member forming a ring around the sensor interface to form an environmental barrier when the sensor interface receives the MEMS sensor module.

12. The device of claim **1** further comprising an anti-rotation pin that mitigates body rotation.

13. The device of claim **1** further comprising means for connecting the body to a wiring harness.

14. The device of claim **1** wherein the sensor interface has a main portion with an elongated shape, and two apertures for accepting legs of the MEMS sensor module.

15. The device of claim **1** wherein the sensor interface is configured to accept the MEMS sensor module in no more than one orientation.

16. A device for removably coupling a MEMS sensor to a vehicle, the device comprising:

a body having means for receiving a MEMS sensor module;

a cable integrally extending from the body; and

means for affixing the body to a vehicle;

the receiving means being configured to accept the MEMS sensor module, the MEMS sensor module being electrically connected with the cable when accepted by the receiving means.

17. The device of claim **16** further comprising means for environmentally sealing the receiving means when accepting the MEMS sensor module.

18. The device of claim **16** wherein the receiving means is configured to removably accept the MEMS sensor module.

19. A method of making a device for removably coupling a MEMS sensor to a vehicle, the method comprising:

forming a body with a sensor interface to accept a MEMS sensor module;

integrally coupling a cable to the body, the cable integrally extending from the body; and

coupling a mounting device to the body, the mounting device being configured to affix the body to the vehicle,

forming further comprising forming the sensor interface so that the MEMS sensor module is electrically connected with the cable when accepted by the sensor interface.

20. The method as defined by claim **19** wherein forming comprises molding the body to form the sensor interface.

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